Overview of EmeraChem:
Progress on NOx Absorber Sulfur Tolerance and ORNL Activities to Advance Development

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Achieving Diesel Product Status with NOx Absorber

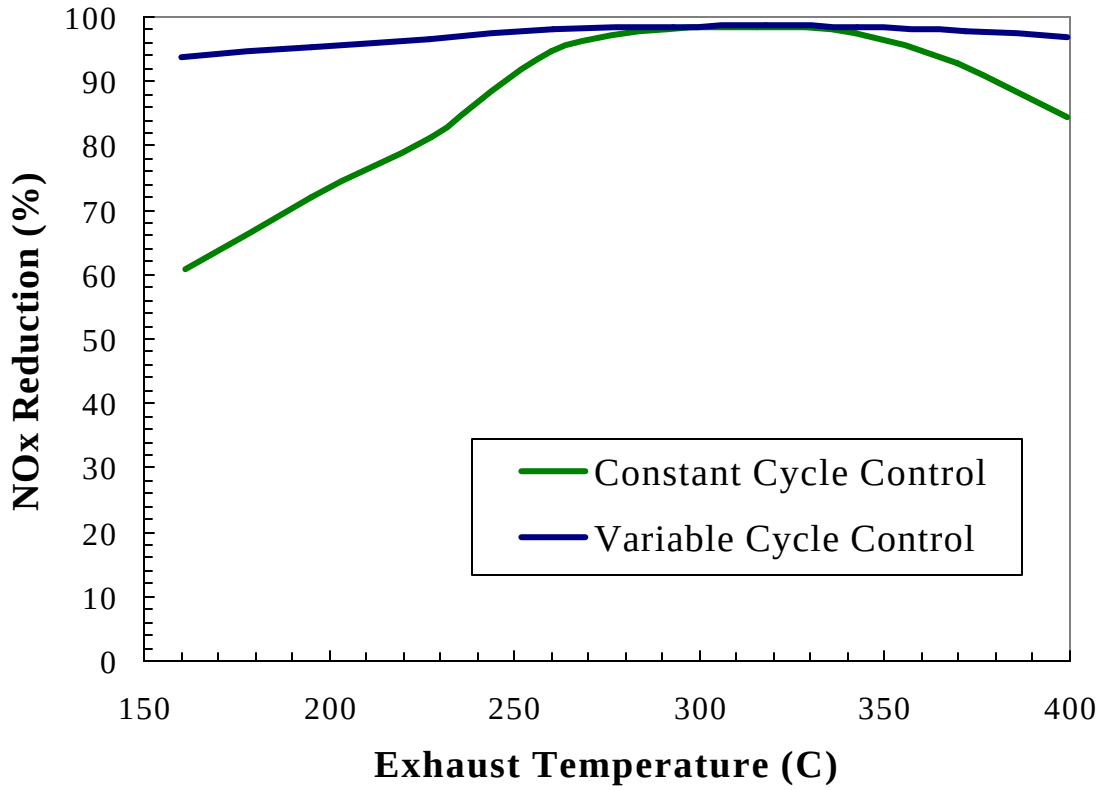
- NOx Absorber Technology is Clean Enough for NOx Emission Regulations
  - <0.2 g/bhp-hr NOx Emissions Demonstrated on 6.9 g/bhp-hr NOx Engine
- Durability is Main Criteria to be Demonstrated
  - Heavy-Duty Regulation Calls for 435,000 Mile Durability
- Most Significant Durability Issue for NOx Absorbers
  - Sulfur Masking of NOx Storage Sites

Key Attributes of EmeraChem NOx Absorber

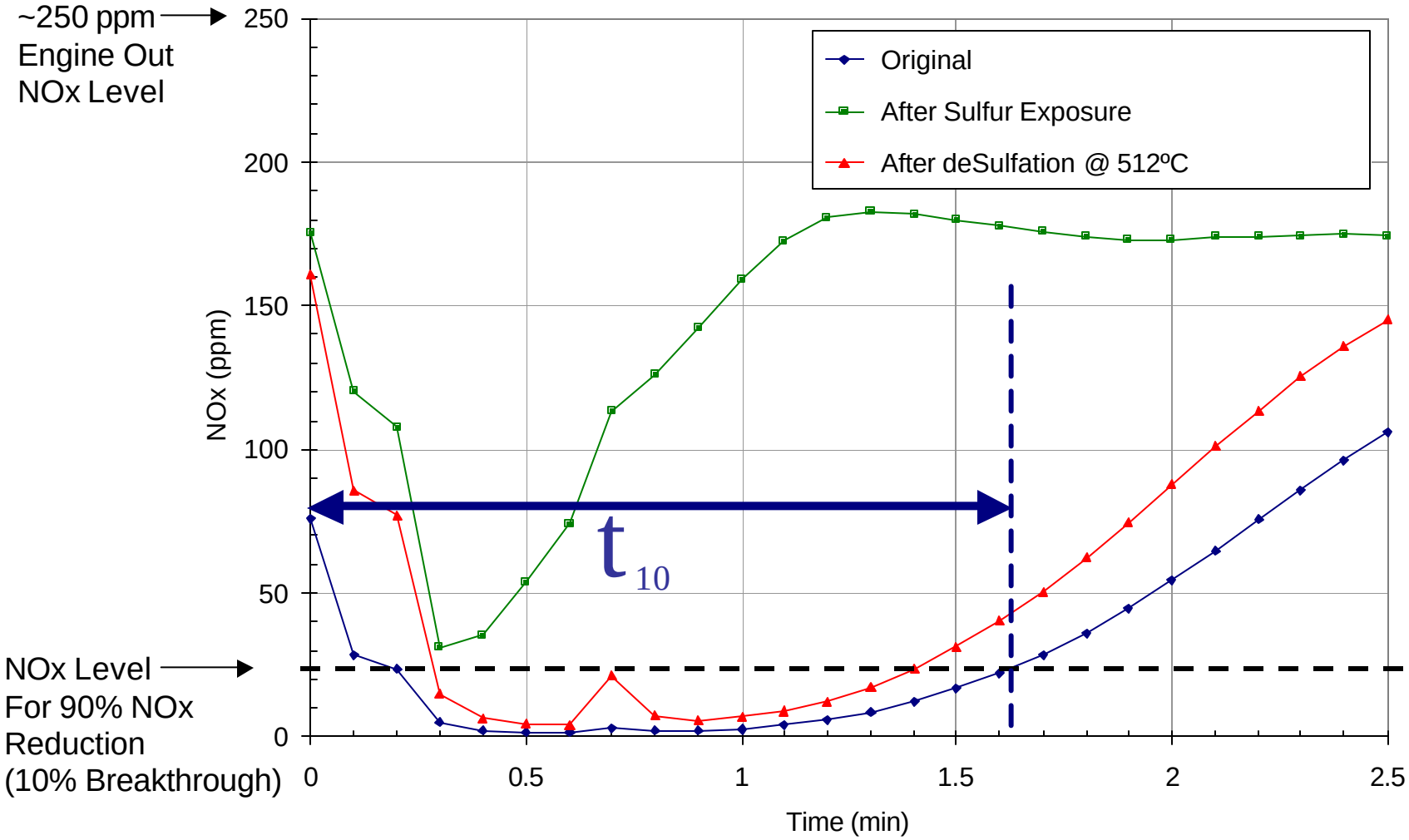
- High NOx Reduction Efficiencies Over a Broad Range of Temperatures Well Suited to Diesel Engine
  - Can Use Diesel Fuel for Catalyst Reductant
- deSulfation at Relatively Low Temperatures (<550ºC)
  - Minimizes Thermal Degradation Occuring During deSulfation
  - Lowers Fuel Penalty for deSulfation
  - Reduces Complications Associated with deSulfation

NOx Absorber Performance for Diesel Exhaust

- Data Obtained on ***11.9 g/bhp-hr NOx Engine*** with ***Diesel Fuel Reductant***
- Constant Cycle Control Data Represents Catalyst Capacity
- Variable Cycle Control Data Represents Engineered Performance
- Fuel Penalties for Constant Cycle and Variable Cycle Data were Similar
  - 3.6% and 3.8%, respectively

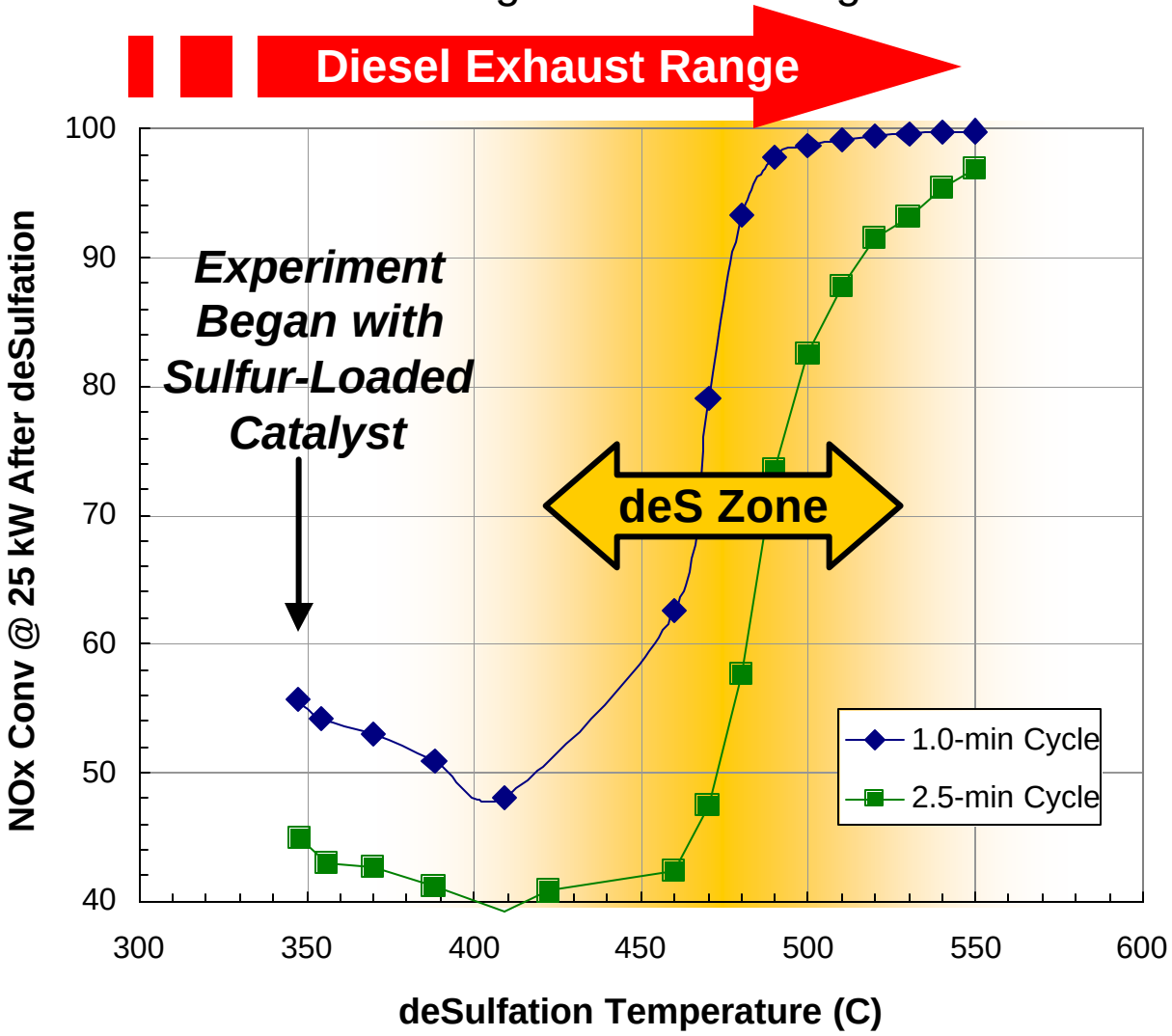


deSulfation Recovery of NOx Capacity: NOx Profiles and Terminology



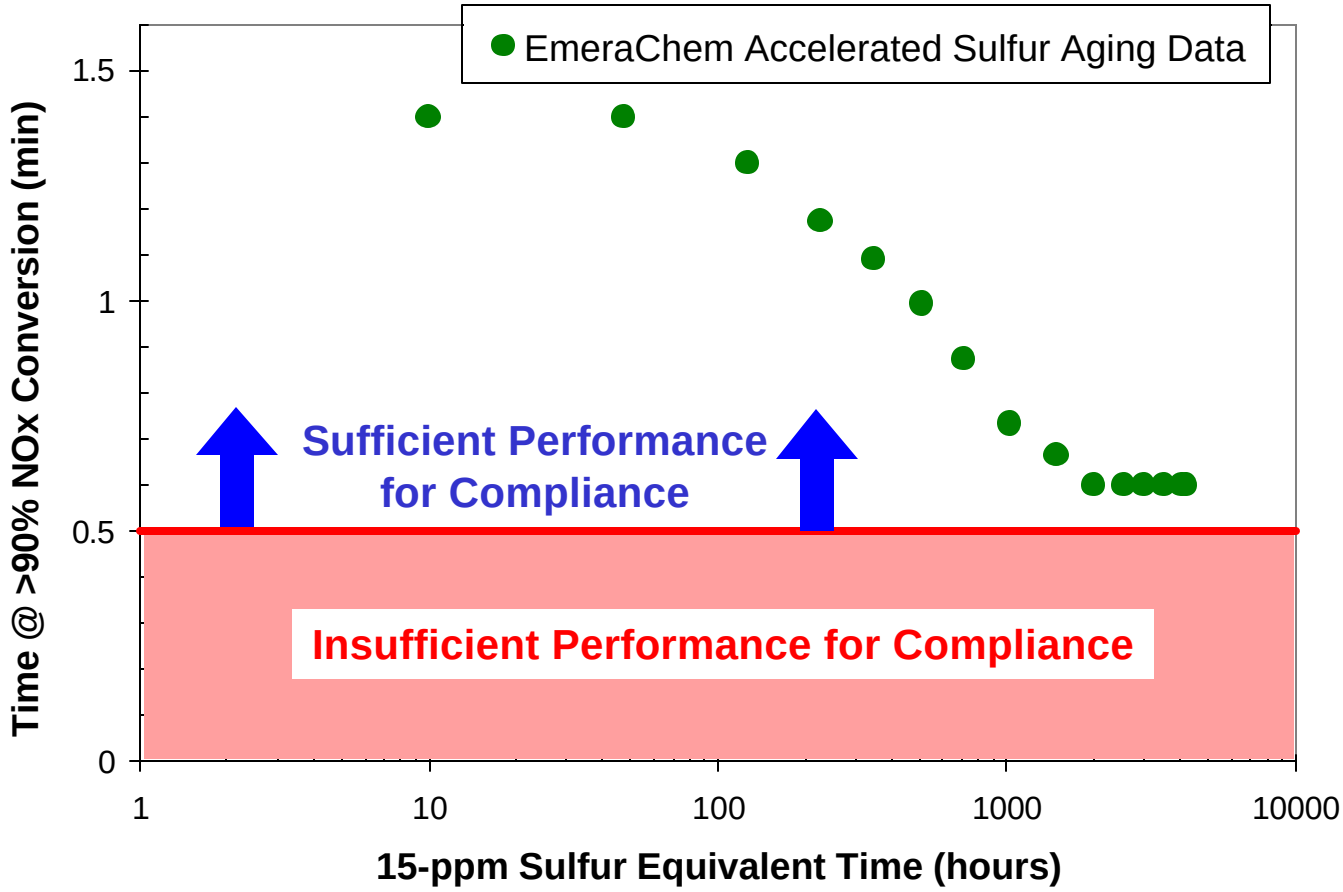
deSulfation in Diesel Exhaust Range

- Data from ***6.9 g/bhp-hr NOx Engine*** with ***NOx Absorber Only*** in System
- Diesel Fuel Reductant Used for Regeneration During deSulfation



Aging on Engine with 150-ppm S Fuel (DECSE)

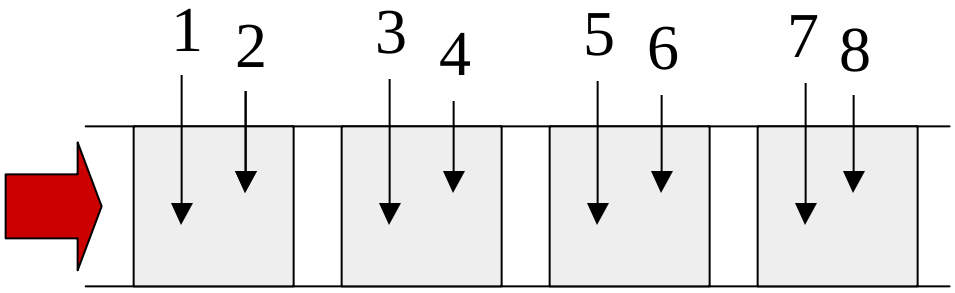
- **Ability to Obtain >90% NOx Reduction Efficiency Maintained**
  - Performance Stabilizes After Initial Thermal Degradation Stabilizes

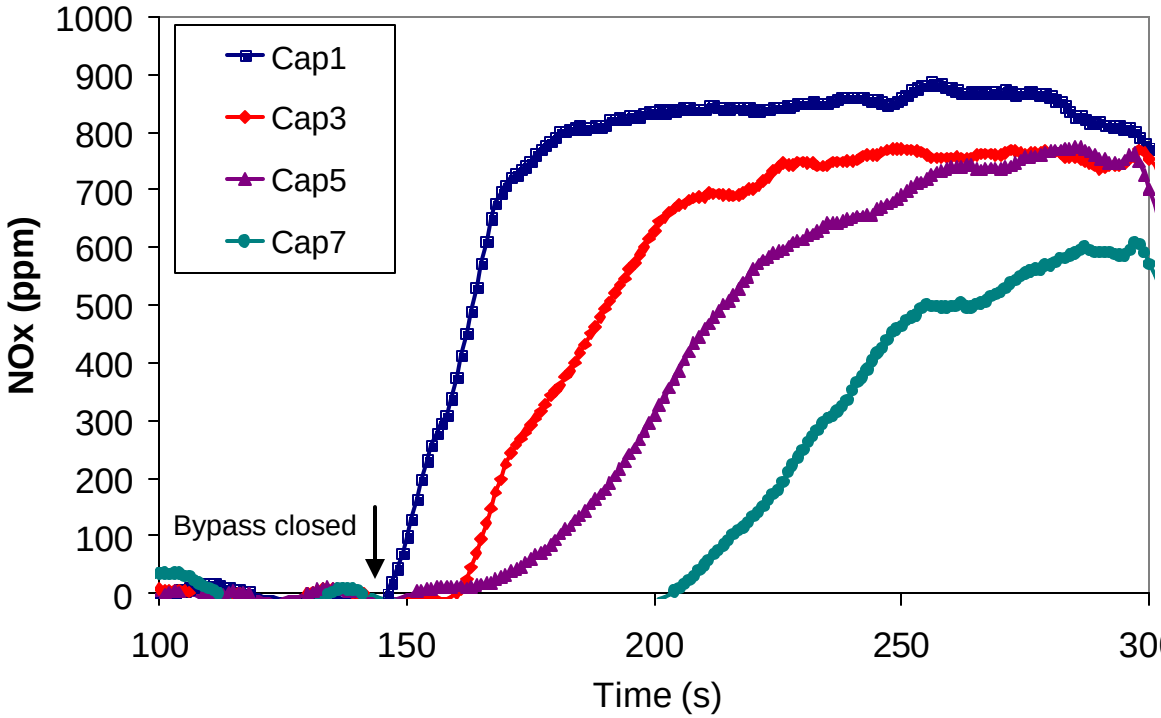


Path to NOx Absorber Product

- While Progress Has Been Made in Sulfur Tolerance for the NOx Absorber Catalyst…
- Development of a NOx Absorber Catalyst Product Will Require:
  - More Understanding of Fundamental Catalyst Mechanisms
  - Characterization of ALL Aging Mechanisms
- US DOE Labs Offer Unique Capabilities to Assist in Development Path

SpaciMS Exhaust Analysis with NTRC

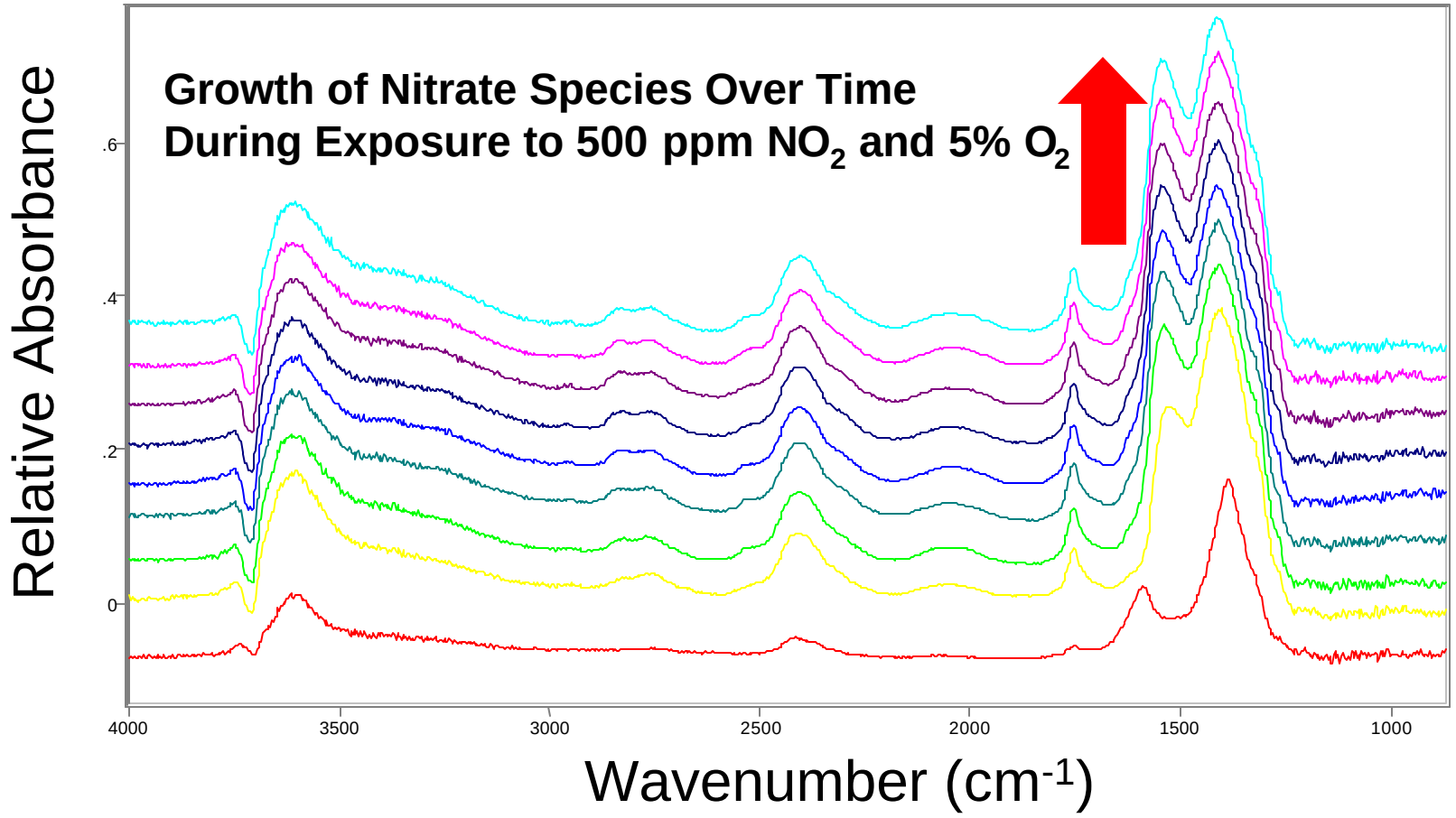




- Exhaust Sampled by 8 Capillaries Distributed Along Flow Axis
- Front third of first catalyst saturates within ca. 20 sec.
- Last catalyst is not used in initial 60 sec.
- Profiles can be used to verify and develop capacity-loading models

DRIFT - Surface Chemistry with NTRC

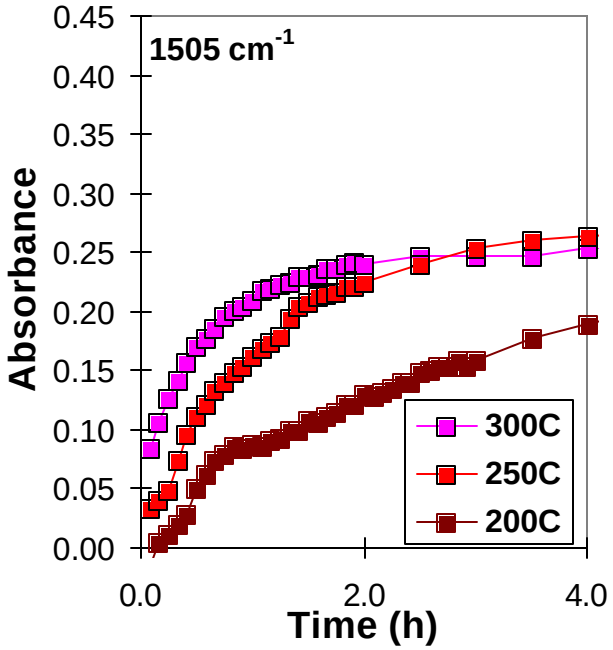
- **DRIFT Detects Unique Solid State NOx Absorber Surface Chemistry**
- **Technique Targeted for Characterization of Nitrate/Carbonate/Sulfates**



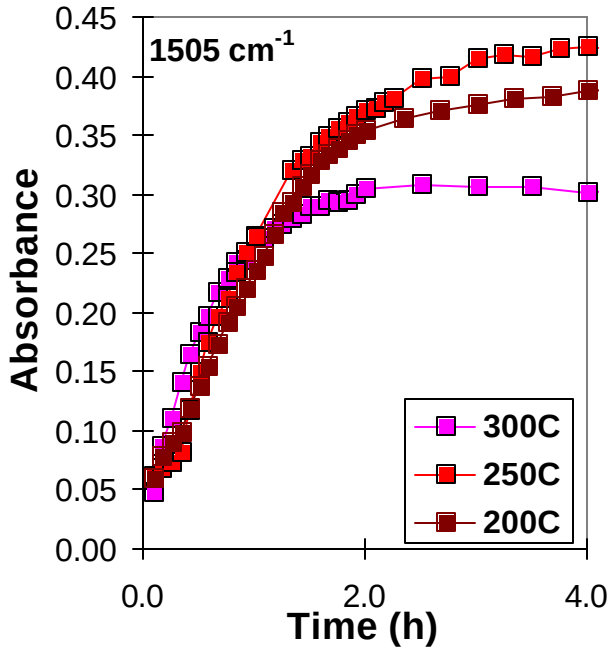
Interesting Differences Observed by DRIFT

- **Differences Observed in Surface Chemistry for NO vs. NO_2 Exposure**
- **More Data Needed to Fully Understand NOx Absorber Mechanism**
- **Fundamentals Will Be Useful in Optimizing Catalyst Performance and Cost**

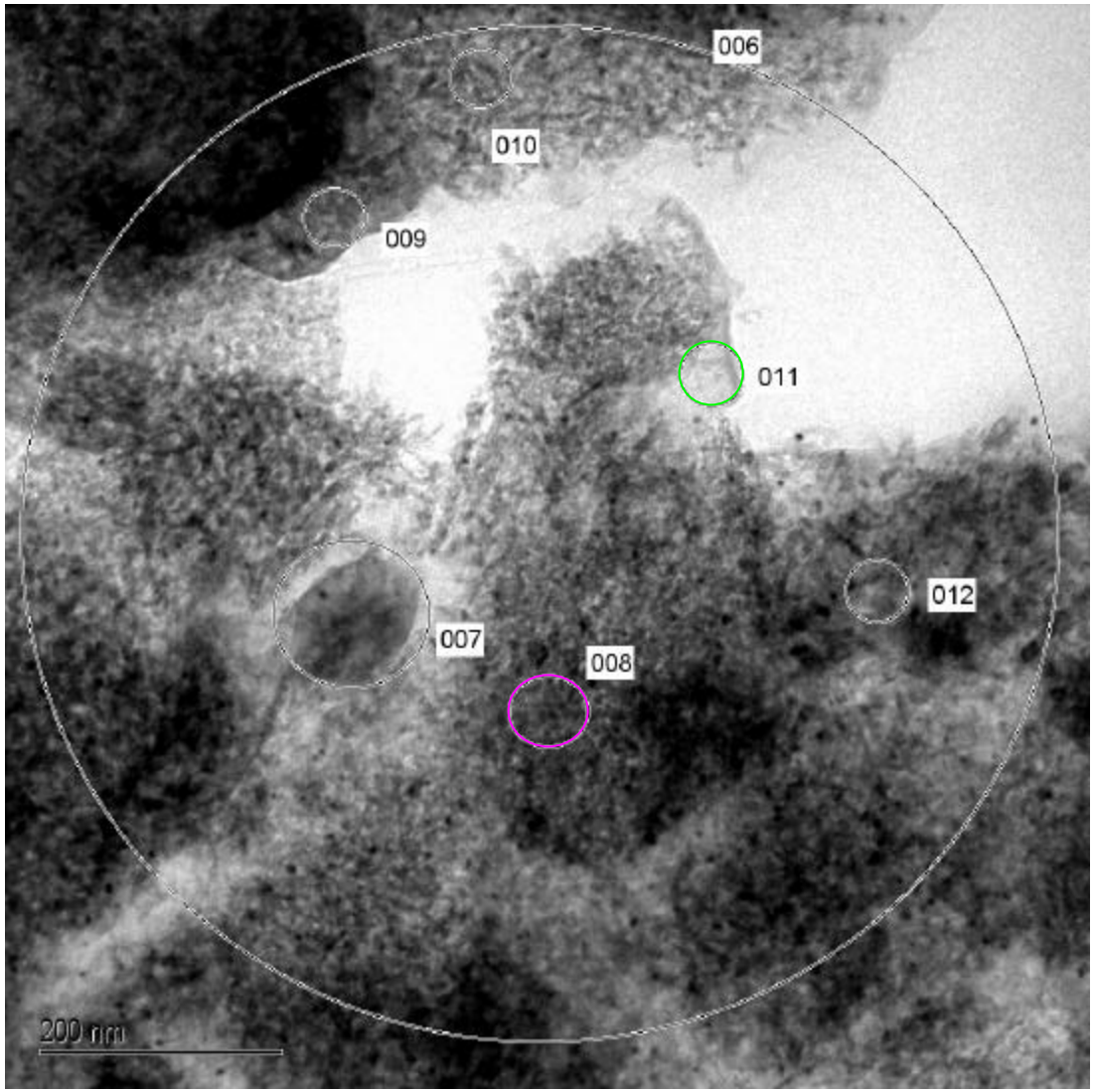
500 ppm NO + 5% O_2



500 ppm NO_2 + 5% O_2



Catalyst Morphology Characterization with HTML



- **TEM Image of K-based NOx Absorber Catalyst**
  - •Catalyst Was Not Aged
  - •Precious Metals Finely Dispersed Over Washcoat
  - •Majority of K Sorbate Finely Dispersed
  - •Some Amorphous K Deposits Occur at Interfaces
  - •Future Studies Will Characterize Aged Catalysts

K Concentration via X-Ray Analysis (a.u.):
Position 011: 560
Position 008: 120
Noise Level: 10

Summary

- NOx Absorber Technology Obtains High NOx Reduction Efficiencies
- Control of Sulfur Effects Demonstrated in Accelerated Aging Studies
- A Greater Understanding of Catalyst Fundamentals Will Lead to an Advanced Cost-Effective Product